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Teamwork delivers biotechnology products to Indian small-holder crop-livestock producers: Pearl millet hybrid "HHB 67 Improved" enters seed delivery pipeline

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Introduction

Pearl Millet (*Pennisetum glaucum*) is grown for grain and stover in the hottest and driest areas of Africa and Asia where dryland crop production is possible. In India 70% or more of the 9 m ha of this crop is sown to genetically uniform single-cross hybrids that are particularly vulnerable to downy mildew (DM) disease, caused by the pseudo-fungus *Sclerospora graminicola* (a close relative of the plant pathogen responsible for the Great Potato Famine in Ireland in the 1840s). DM is the most important disease of this crop in Asia and Africa, causing up to 30% production losses at the national level in years of epidemics.

HHB 67, released in 1990 by CCS Haryana Agricultural University, is one such single-cross pearl millet hybrid. HHB 67 is highly popular because of its extra-early maturity (it needs less than 65 days from sowing to grain maturity) and is now grown on over 500,000 ha in Haryana and Rajasthan. Recent surveys have indicated that this hybrid is starting to succumb to DM, showing up to 30% incidence in farmers' fields.

Development

Hybrid HHB 67 is highly preferred and has been rapidly and widely adopted by farmers, so its parental lines were chosen for DM resistance maintenance breeding in an attempt to break the boom-bust cycles that have characterized pearl millet hybrid cultivation in India since the late 1960s. Marker-assisted backcrossing with elite donor parent ICMP 451 was used to add DM resistance to male parent H 77/833-2. The marker system used was restriction fragment length polymorphism, which nearly everyone agrees is too slow, too cumbersome, and too expensive to use as a selection tool in applied plant breeding. However, the challenge was taken up by Arun Sharma, a Plant Breeding PhD scholar from Haryana Agricultural University working under the guidance of DC Nijhawan and ICRISAT's CT Hash. Additional genes for DM resistance were backcrossed into female parent 843A/B from donor ICML 22 using conventional progeny-based greenhouse screening of pot-grown seedlings. Conventional backcross transfer of DM resistance to improve 843A/B took nearly nine years (1991-1999), while marker-assisted backcross

transfer of DM resistance to improve H 77/833-2 was completed in just over three years (1997-2000). Initial testing of hybrid combinations of the improved parental lines was performed at ICRISAT during the rainy season of 2000.

Testing

Greenhouse disease screening confirmed the improved DM resistance of the new versions of the parental lines and their hybrids. Hybrids were tested across 6 sites in collaborative trials conducted during the 2001 rainy season. Two of the improved versions of HHB 67 were subsequently compared for agronomic performance with the original in three years (2002–2004) of on-station state trials in Haryana, on-station national trials of the All-India Coordinated Pearl Millet Improvement Project (AICPMIP), and >100 on-farm trials conducted in several districts of Haryana where HHB 67 had become the most popular pearl millet cultivar over the past 15 years. In these three years of testing, farmers expressed a clear preference for the taller of the two improved hybrids, which is slightly taller (15–30 cm), later (2–3 days), has higher grain and stover yields (5–10%) than the original HHB 67, as well being more resistant to DM and having easily recognizable long, thin panicles with short bristles (sort of like "designer stubble" on the cheeks and chin of popular lead actors in Hindi films).

Release

After three years testing in national trials, the Haryana State Varietal Release Committee on 14 Jan 2005 approved release of this taller, short-bristled improved version of pearl millet hybrid HHB 67 for cultivation in Haryana. After sorting out a few bureaucratic details, its State Release as "HHB 67 Improved" was approved by the Central Plant Variety Release Committee on 29 June 2005, and this was quickly followed in July by approval of its All-India release (which was notified in the Gazette of India in November 2005). "HHB 67 Improved" is the first product of marker-assisted breeding to reach cereal producers in India. It is also among the first public-bred marker-assisted breeding products commercialized in developing countries globally, following release in Indonesia in 2001 of several rice varieties bred by this technique.

Priming the hybrid seed multiplication pipeline

Large quantities of Breeder Seed of the parental lines of "HHB 67 Improved" were distributed in 2005-06 to public and private seed agencies by ICRISAT and Haryana Agricultural University following approval of the hybrid's release by central government authorities in India. Due to regulatory delays in the release process, much of the Breeder Seed distributed in 2005 was used directly for Certified Seed production of the new hybrid itself rather than multiplication of parental line Foundation Seed. However, this should ensure that Certified Hybrid Seed is available to sow >50,000 ha with "HHB 67 Improved" during the 2006 rainy season. Further parental line seed multiplication during 2006 will ensure that "HHB 67 Improved" can swiftly replace the original, before downy mildew inoculum levels build up enough to cause an epidemic.

Economic Benefits

By rapidly adopting hybrid "HHB 67 Improved", farmers in Haryana and Rajasthan can avoid grain production losses of Rs36 crores (US$8 million) which would be expected in the first year of a major DM outbreak on the original HHB 67. In years of severe DM attack, up to 30% of the pearl millet grain and straw harvest can be lost. The income losses for grain alone in a severe DM outbreak on HHB 67 can be estimated conservatively assuming an average grain yield of 800 kg per ha (most of the HHB 67 area is in Haryana, which has recently had state average pearl millet grain yields in excess of 1000 kg per ha), and a minimum selling price of Rs3 per kg (prices range from around Rs2 immediately after harvest in years of bumper crops, upwards to Rs6 per kg). The value of these potential grain yield losses—in the first year of a major DM epidemic on the original HHB 67—exceeds the total research funding support provided by DfID during the period 1990 through 2005 for research activities related to the development and application of marker-assisted breeding tools for pearl millet. Any future applications of these tools (as well as benefits from avoidance of grain and stover yield losses in the second year of the epidemic) will represent profits to society as a whole from this well-spent research investment.

Summary

Marker-assisted backcross improvement of DM resistance of H 77/833-2 and initial trials that identified the best improved versions of HHB 67 as a promising hybrid combinations were supported by a series of research grants from the Plant Science Research Programme of the UK's Department for International Development (DfID) to ICRISAT and its research partners. "HHB 67 Improved" is the first product of marker-assisted breeding to be proposed for release for cultivation in India. It is a product of long-standing partnerships supported in part by the DfID Plant Sciences Research Programme (which funded development of the tools for pearl millet marker-assisted breeding, provided support for Dr Arun Sharma's PhD thesis research studies at ICRISAT-Patancheru, and provided equipment to strengthen a marker lab in CCSHAU's Plant Breeding department), that involved UK-based partners at the John Innes Centre in Norwich, University of Wales in Bangor, and the Institute of Grassland and Environmental Research near Aberystwyth; the All-India Coordinated Pearl Millet Improvement Program, and the pearl millet improvement teams of ICRISAT and the CCS HAU Department of Plant Breeding. Without the active involvement of all of these partners, it would not have been possible to breed, test, and release this product—which is very much wanted by Haryana farmers. Long-term (>15 years) support from the DfID PSP management team was a critical contributing factor. This is a partnership that deserves to be celebrated, emulated, further improved and propagated. It clearly demonstrates how partners with widely disparate interests can come together, each contributing something for which they have comparative advantage, to deliver appropriate research products targeted to meet the needs of the poor, while pursuing each part of the group is simultaneously pursuing its individual interests. The efforts required to coordinate this "herd of cats" have been richly rewarded.